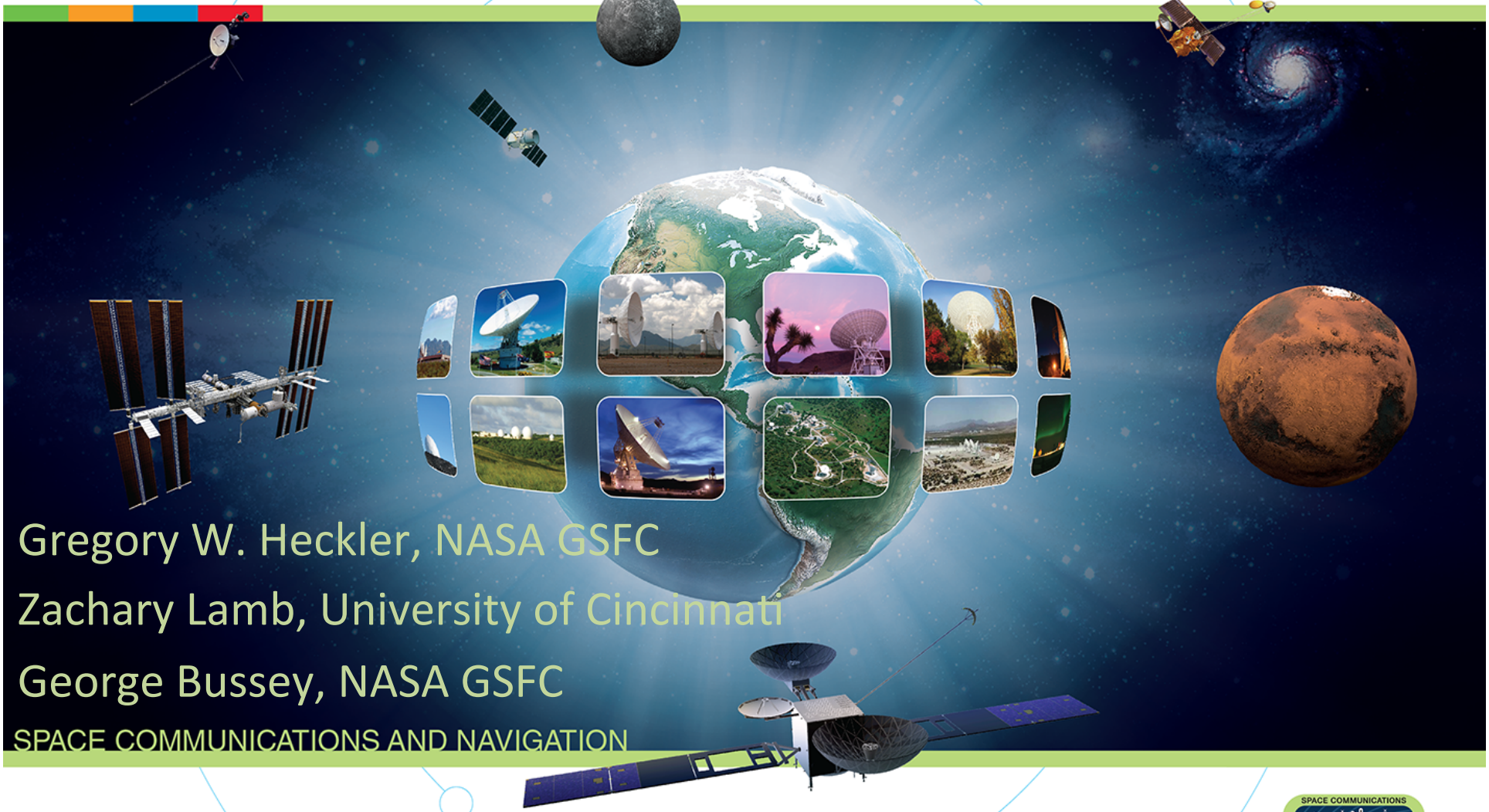
Space Network Data Mining

National Aeronautics and Space Administration



Gregory W. Heckler, NASA GSFC

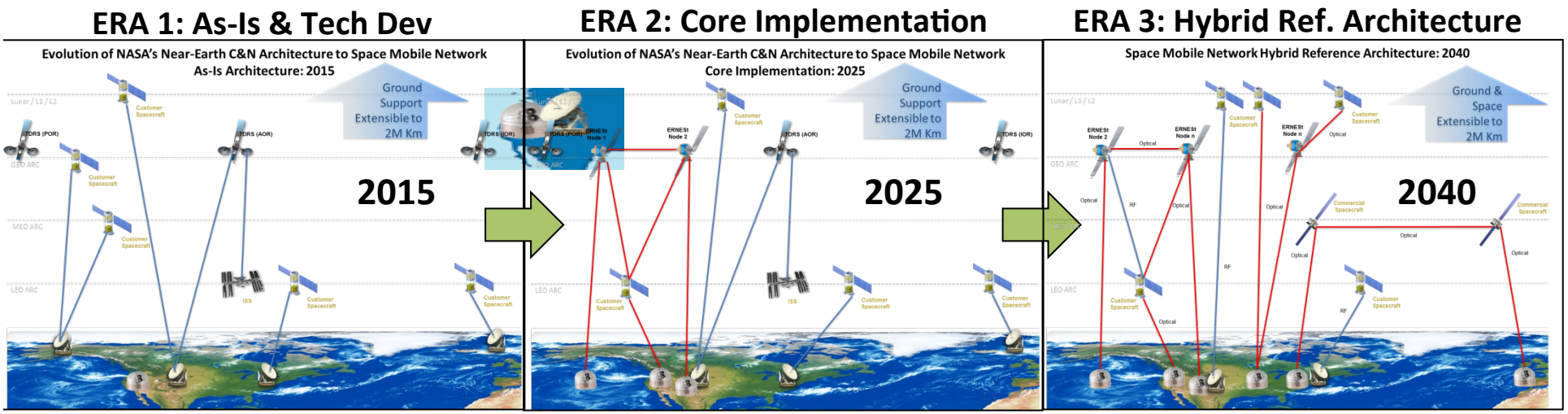
Zachary Lamb, University of Cincinnati

George Bussey, NASA GSFC

SPACE COMMUNICATIONS AND NAVIGATION

SPACE COMMUNICATIONS SCaN AND NAVIGATION

SN and NEN Evolution

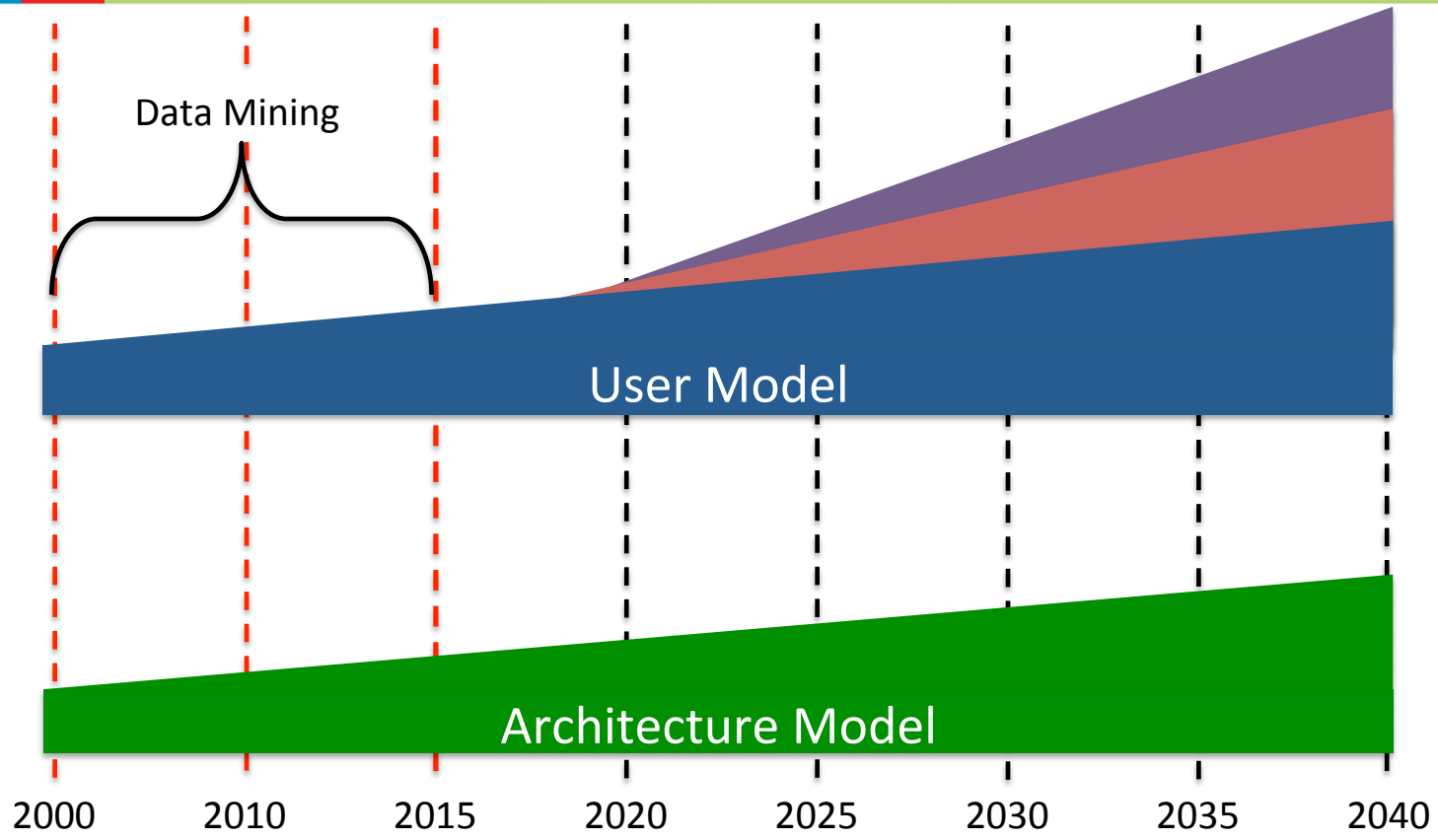


By developing the Space Mobile Network, NASA has the opportunity to:

- lead the next generation of space communication and navigation;
- realize an all optical space network
- potentially reduce communication infrastructure costs;
- ensure interoperable standards and protocols exist that provides US Commercial industry a head start;
- and provide an engine to help drive the U.S. and global economy.

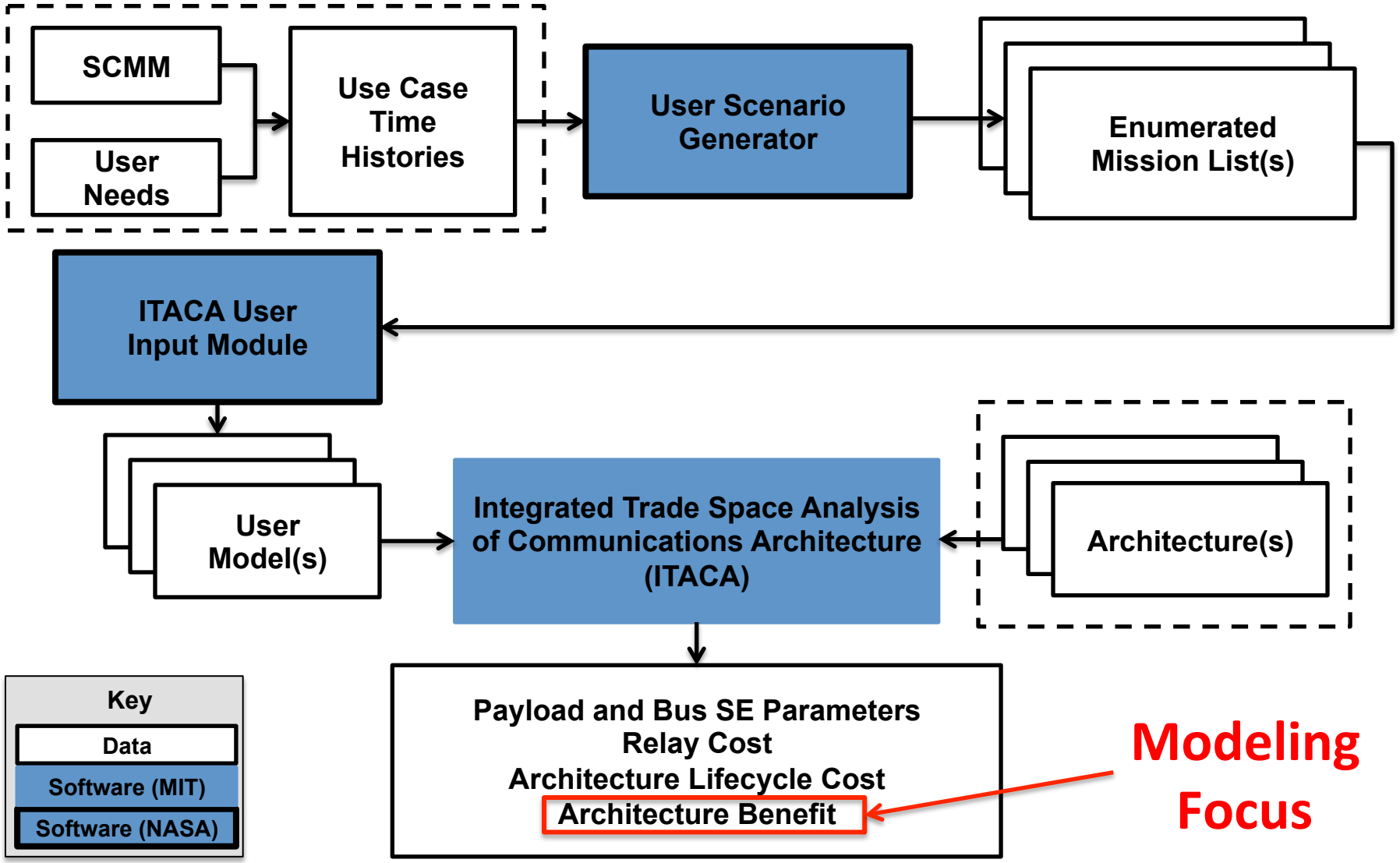
The new management paradigm enables an incremental capability approach, which together, allow for efficient transition from current state to 2040 Hybrid Reference Architecture

Modeling the (R)evolution



- An architecture model is a single time history of architecture **assets**, their **capabilities**, and their **locations**
- A user model is a single time history of **users**, their **needs**, and their **locations**

Analysis Process



User Model: Data Sources

SN Daily Operations Report

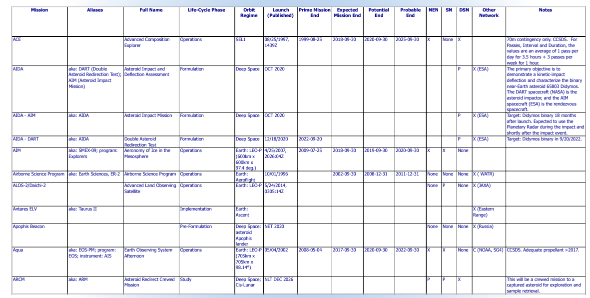
Space Network Customer Support

	TDRS-09	TDRS-12 Low	TDRS-06	TDRS-03 S-Band	TDRS-05 S-Band	TDRS-11 Low	TDRS-10	TDRS-08 Low	TDRS-07				
LOCATION	12.0W	41.1W	46W	62.4W	167.5W	171W	174W	271W	275W				
SGLT	8	2	5			4	1	7	6				
DESIGNATOR		TDE/DASE	TDS		150	171/DASW	TDW		TDZ/DASZ				
ANTENNA	B-South	S-Central	W-Central	S-STTC	W-STTC	W-North	S-North	G-South	G-Central	DAS	Total	Schedule	Loss
AIM		4	14			13			12		43	27:39:48	00:00:00
AQUA		10	16			8	14		5		53	31:50:23	00:00:00
ATLAS-V		1				1					2	1:21:00	00:00:00
AURA		5	12			11	6		1		35	27:16:47	00:00:00
FGST		5	6			5	3			43	62	44:20:58	00:00:00
GPM		8	6			11	3		14		42	28:51:08	00:00:00
HST			6				10				16	29:13:10	00:00:00
ISS		15	1			2	15		2		35	84:14:04	00:00:00
LSAT-7		1				1					2	0:59:00	00:00:00
MMS-1		1				2					3	1:46:00	00:00:00
MMS-2		1				2					3	1:30:00	00:00:00
MMS-3		1				2					3	1:30:00	00:00:00
MMS-4		1				2					3	1:54:00	00:00:00
NEOWISE		1	1			1	1				4	4:02:49	00:00:00
NUSTAR		1									1	0:24:00	00:00:00
SCaNTB JPL						2					2	0:30:35	00:00:00
SORCE		7	9			8	1		12		37	28:13:22	00:00:00
SP&M											60	145:02:54	00:00:00
SPTR-2			4								4	14:04:00	00:00:00
SWIFT										42	42	23:51:59	00:00:00
TERRA		5	11			8	5				29	25:52:48	00:00:00
TOTALS											481	524:28:45	0:00:00
BRTS		22	14			18	18		14				

Note: Unless otherwise indicated, all TDRS S/C are at the common frequency, K-Band.

File type: pdf
Data: daily SN usage by mission, some NEN usage by mission

Space Communications Mission Model (SCMM)



File type: xls
Data: communication needs, mission start/stop dates

Use by Asset/Service Time
Use by Data Volume
Use by Frequency Band
Use by User
Long Term Trends
etc…

SGSS Customer List

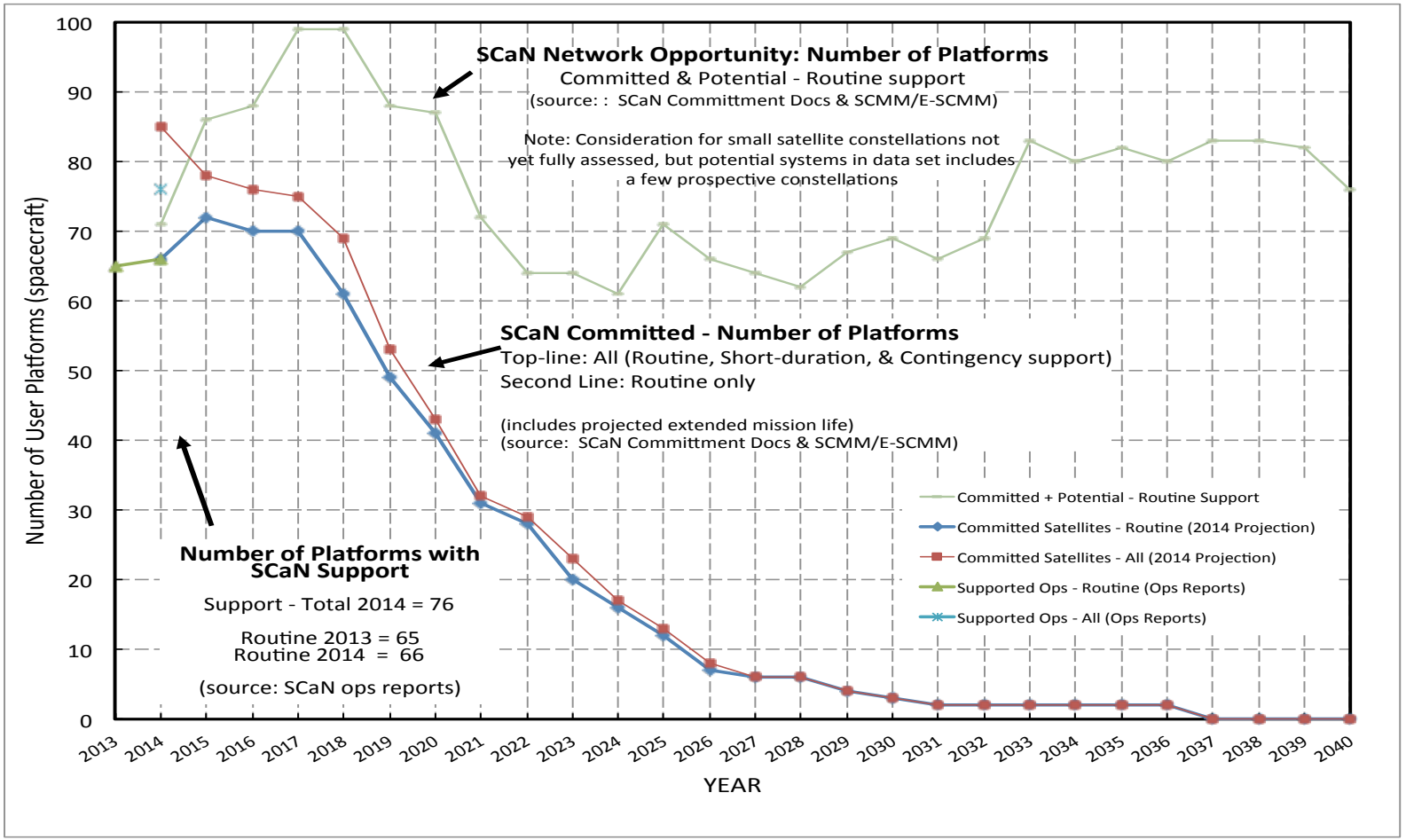
Mission	RLBP Links				RLBP Link Characteristics											
	Platform	Space Link Type	Ground Link Type	Initial Data Rate (bps)	User Platform to TDRS RF Rx 10.1 SSC	Acquisition Process 10.2 SSC	DeModulation 11.1 SSC	Symbol Processing 11.2 SSC	Frame Sync and DQM 11.3 SSC	Frame Processing 11.4 UIFC	TCP Socket MOC Inf 12.1.1 UIFC	SLE MOC Inf 12.1.2 UIFC	IF ULE Inf 12.2 UIFC	BB ULE Inf 12.3 UIFC	UDP BB MOC Inf 12.4 UIFC	Record Playback 13.1 UIFC
SCAN Test Bed	Harris	KaSAR	BB ULE (I)	300000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	Harris	KaSAR	BB ULE (I)	100000000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	Harris	KaSAR	BB ULE (I)	150000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	Harris	KaSAR	BB ULE (I)	150000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	Harris	KaSAR	BB ULE (I)	150000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	Harris	KaSAR	BB ULE (I)	150000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	Harris	KaSAR	BB ULE (I)	300000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	Harris	KaSAR	BB ULE (I)	300000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	Harris	KaSAR	BB ULE (I)	300000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	SSAR	BB ULE (I)	24000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	SSAR	BB ULE (I)	24000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	SSAR	BB ULE (I)	24000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	SSAR	BB ULE (I)	24000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	KaSAR	BB ULE (I)	150000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	KaSAR	BB ULE (I)	300000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	SMAR	BB ULE (I)	192362	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	SMAR	BB ULE (I)	24000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	MAR	BB ULE (I)	24000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	SMAR	BB ULE (I)	24000	A	A	A	A	N/A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	SMAR	BB ULE (I)	24000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	SSAR	BB ULE (I)	24000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	KaSAR	BB ULE (I)	300000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A
SCAN Test Bed	JPL	KaSAR	BB ULE (I)	150000	A	A	A	A	A	N/A	N/A	N/A	N/A	A	N/A	N/A

File type: xls
Data: SN services, by mission

SN Schedule Database Extract

File type: Oracle DB
Data: scheduled SN services, by *obfuscated* mission

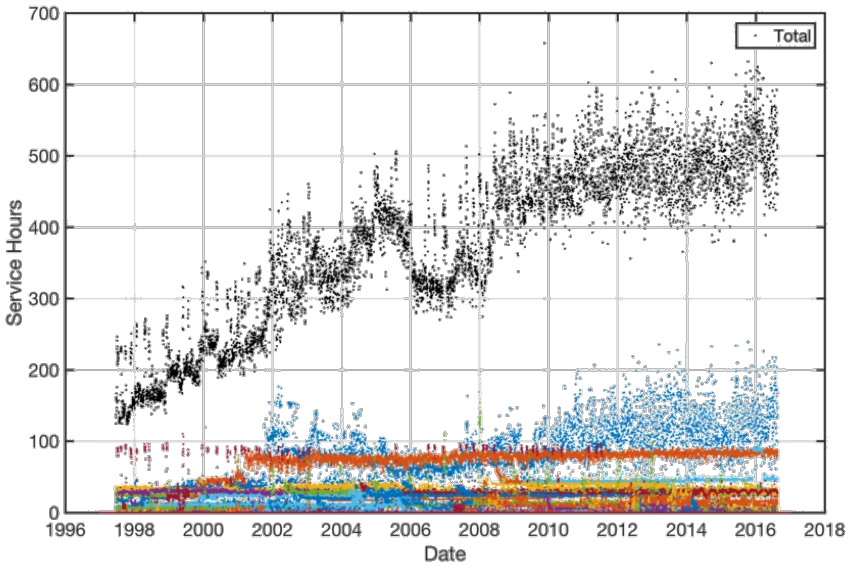
Space Communications Mission Model (SCMM)



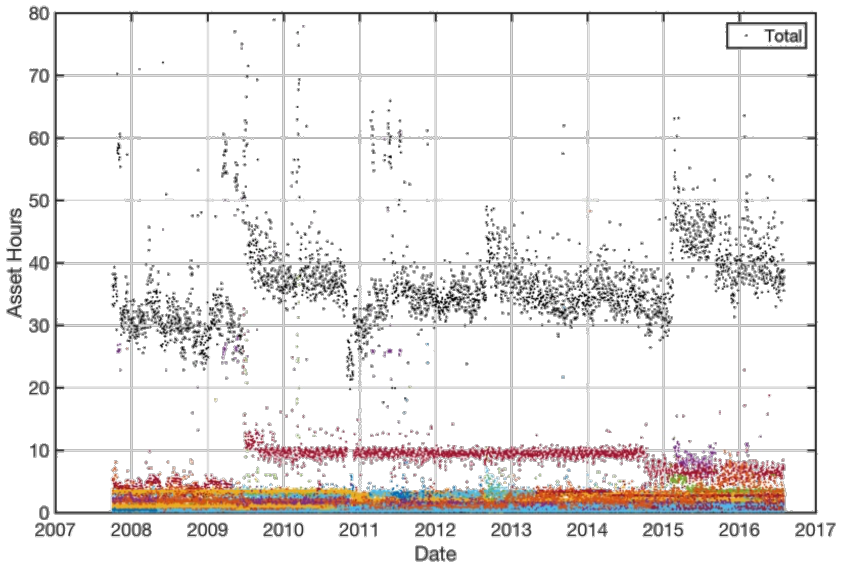
- **Includes all SCaN-committed missions, and**
- **All key stakeholder planned and potential missions (e.g., AOs)**

SN & NEN Daily Report

Space Network



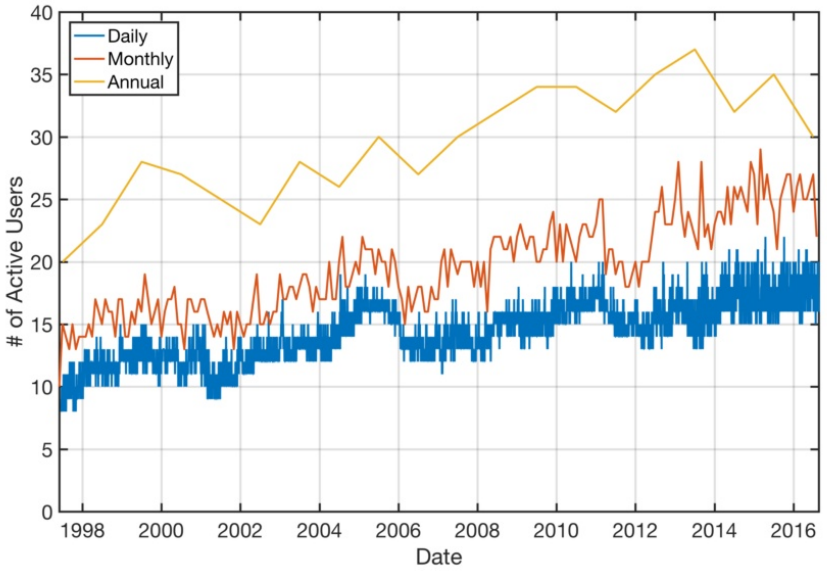
Near Earth Network



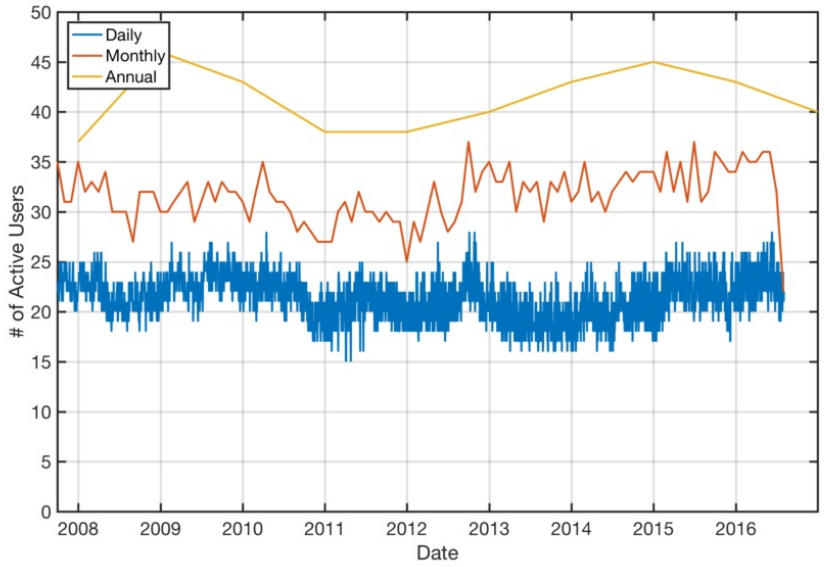
- SN daily report from 1997 – present
  - Intern delivered JAVA utility to process new pdfs
  - Cleaned/consolidated data into two spreadsheets: daily usage, daily loss
  - 681002 individual records
  - Service hours = sum of all services in an event: SSAF, SSAR, TRK = 3x event length
- NEN daily summary from 2008 – present
  - Provided mission, asset, AOS time, LOS time
  - 439992 individual records

SN & NEN Daily Report

Space Network



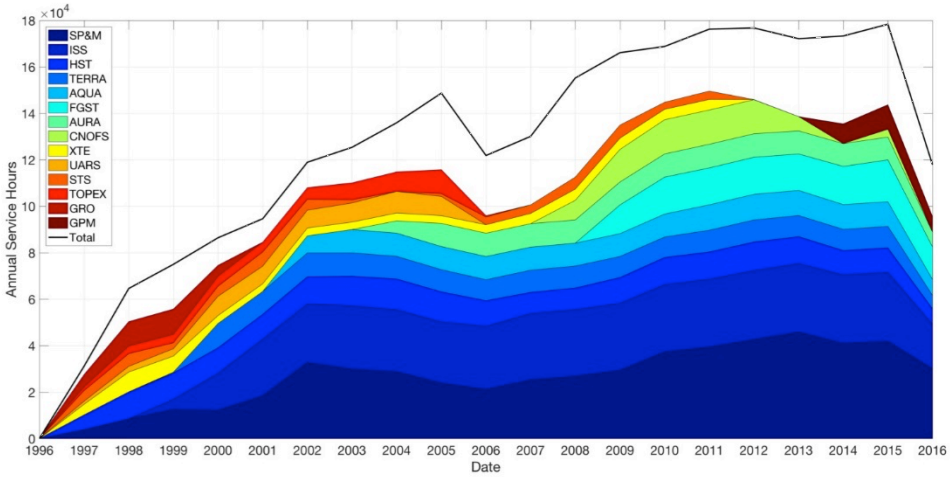
Near Earth Network



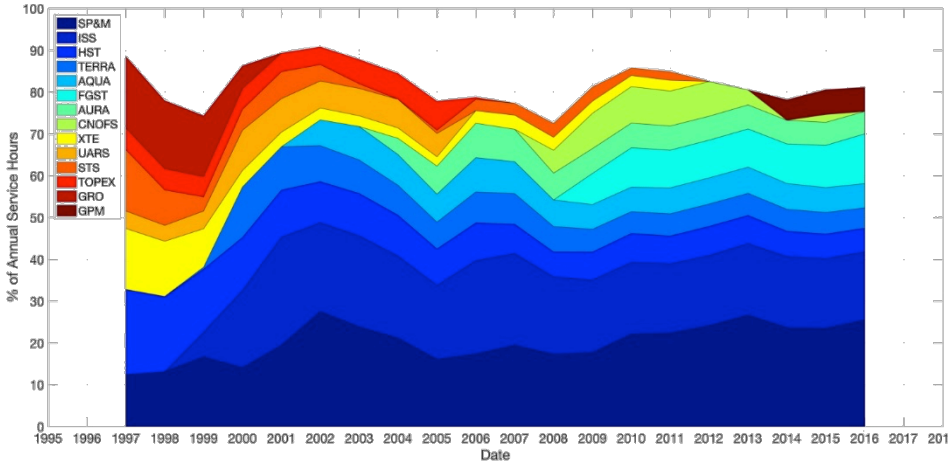
- The number of daily, monthly, and annual users is increasing
- Monthly users 40% greater than daily users
- Annual users 50% greater than monthly users

SN & NEN Daily Report

Total Hours



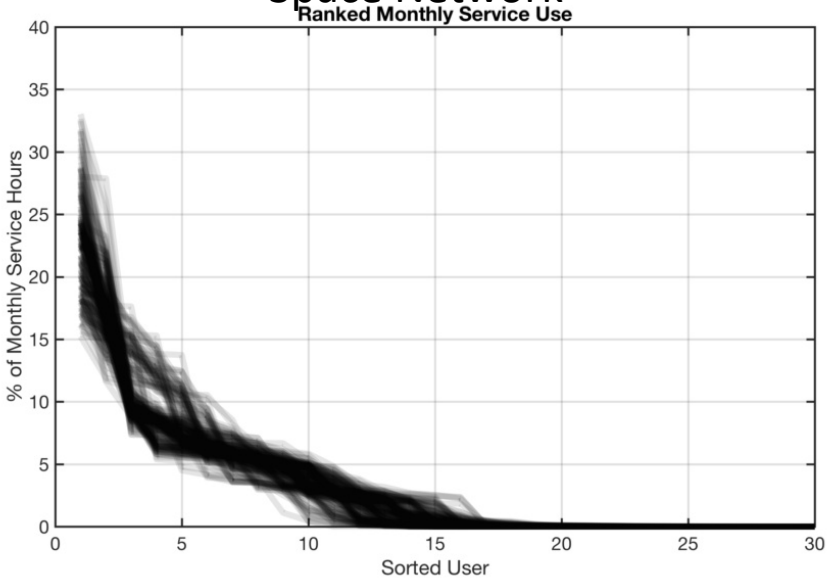
Normalized



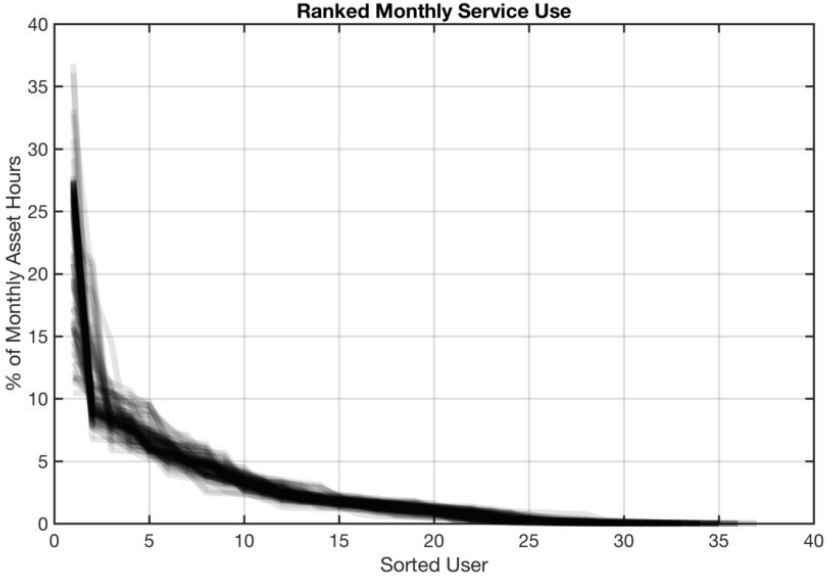
- Usage driven by “top ten” customers
- Daily usage growth has slowed, *temporarily*
  - SN constrained by ground assets: BPRS, GRGT, & SGSS upgrades will expand capacity
  - SN constrained by space assets: TDRS KLM will expand capacity
  - Several high demand users are expected in near/middle term:
    - ISS upgrade to 600 Msps service
    - JPSS1, JPSS2+, …

SN & NEN Daily Report

Space Network

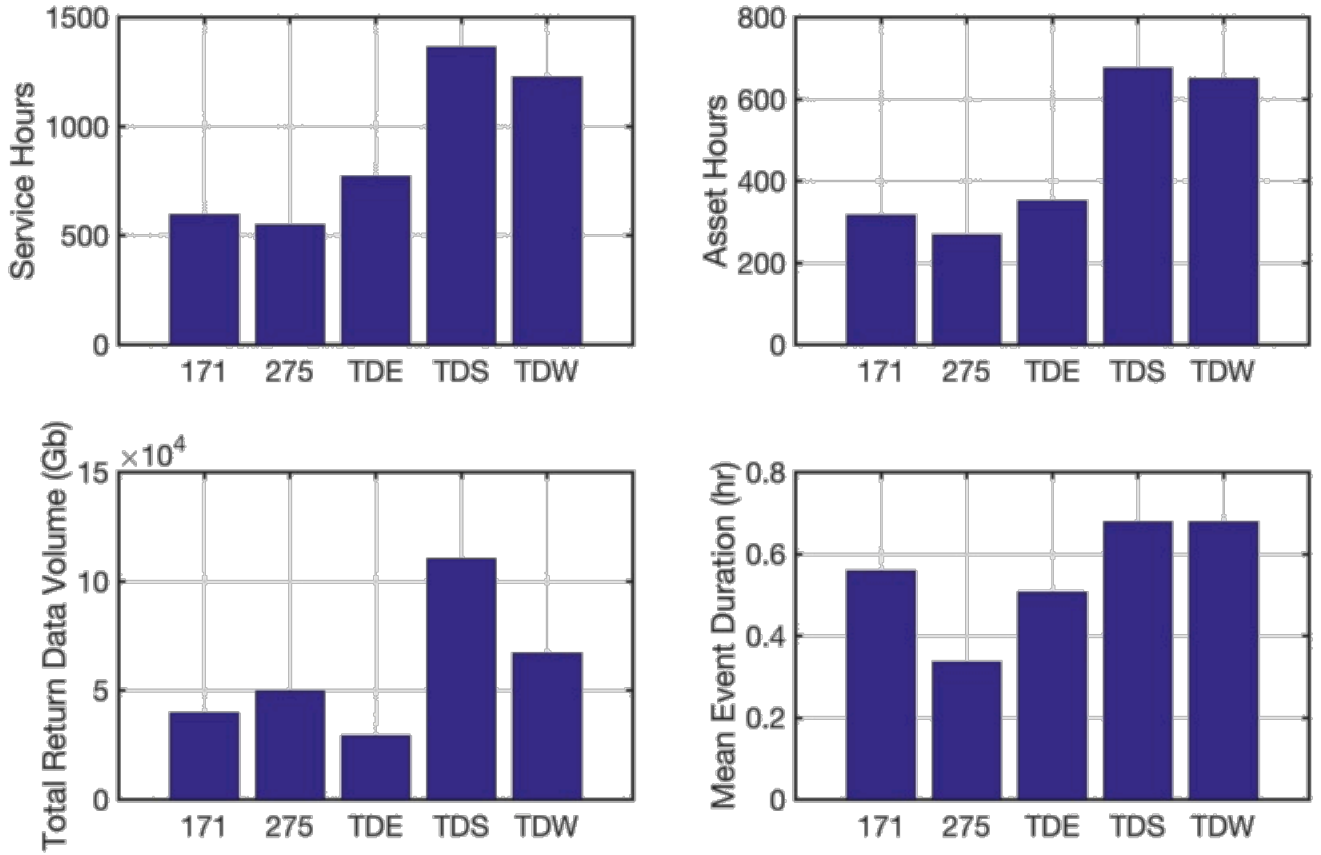


Near Earth Network



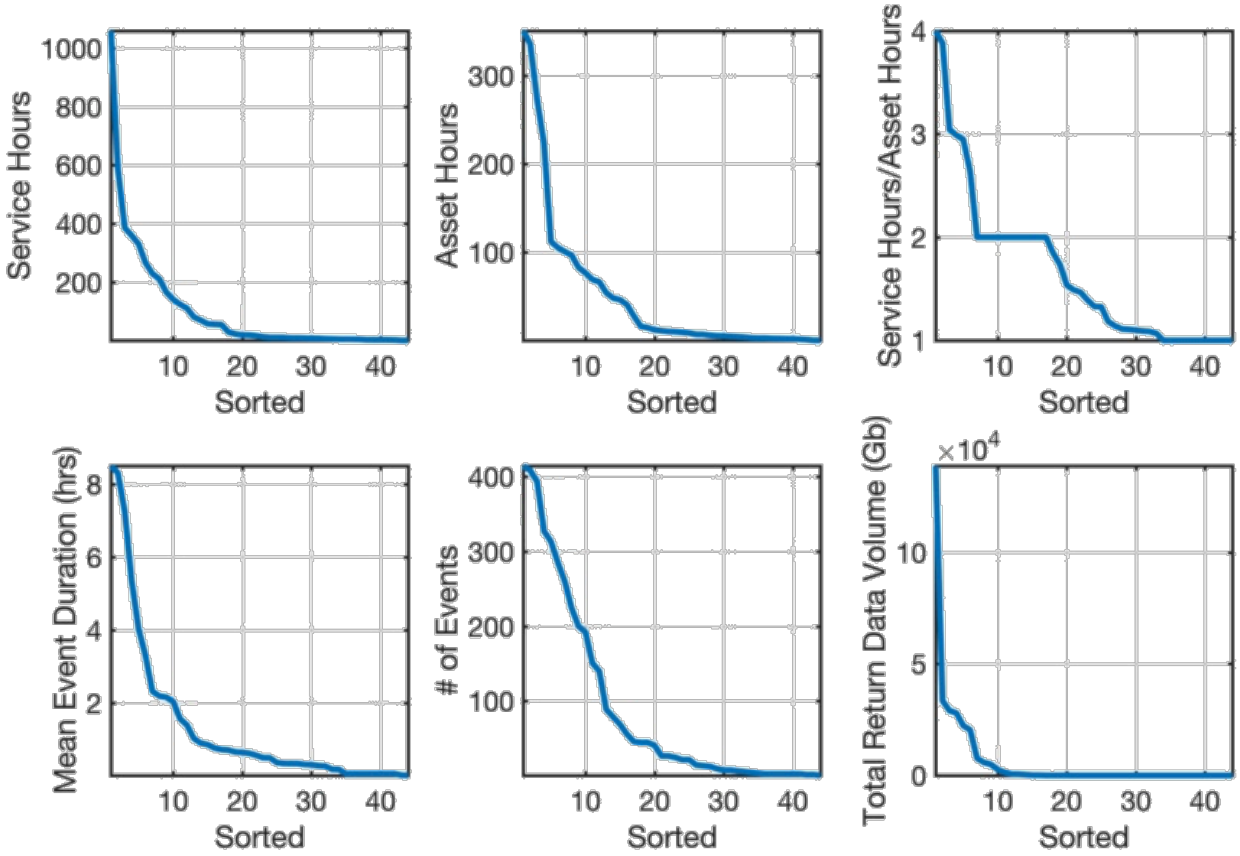
- Usage follows a long tail (power law) distribution
- Are long tail distributions evident in other areas?
- SN daily report itself not traceable to a con-ops:
  - asset time
  - data volume
  - contact duration
  - # of events/day
- Need additional data to derive con-ops

SN Schedule Database



- 13 day Oracle DB schedule from May 2012
- 4013 unique events, 44 *obfuscated* users

SN Schedule Database



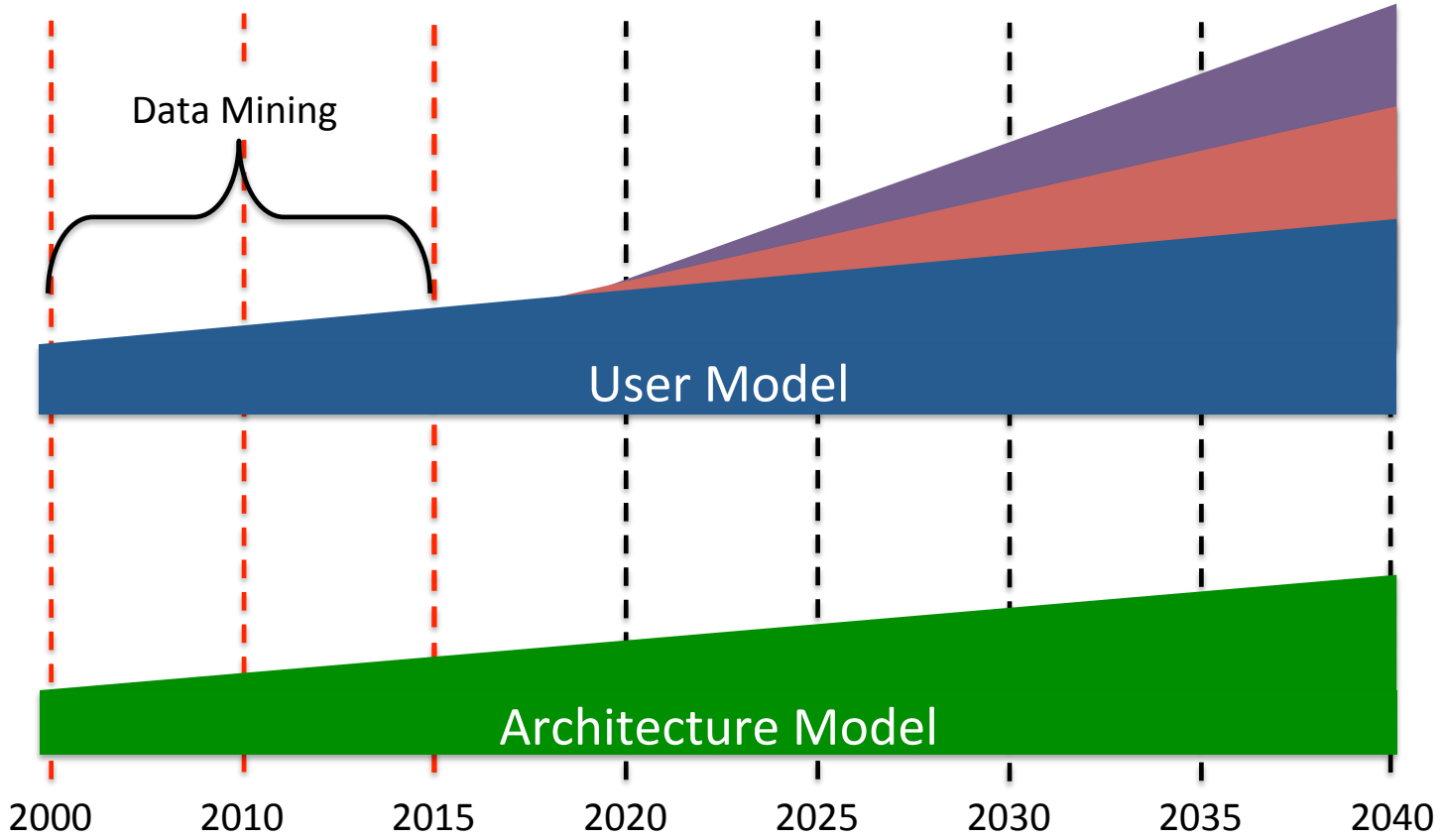
- Power law distributions evident in many different views of the dataset
- But…

SN Schedule Database

- Service hours is correlated to asset hours, # of events, return data volume, and forward data volume
- Pass duration is uncorrelated with network usage, by time or by data volume
- Pass duration is slightly negatively correlated with # of events

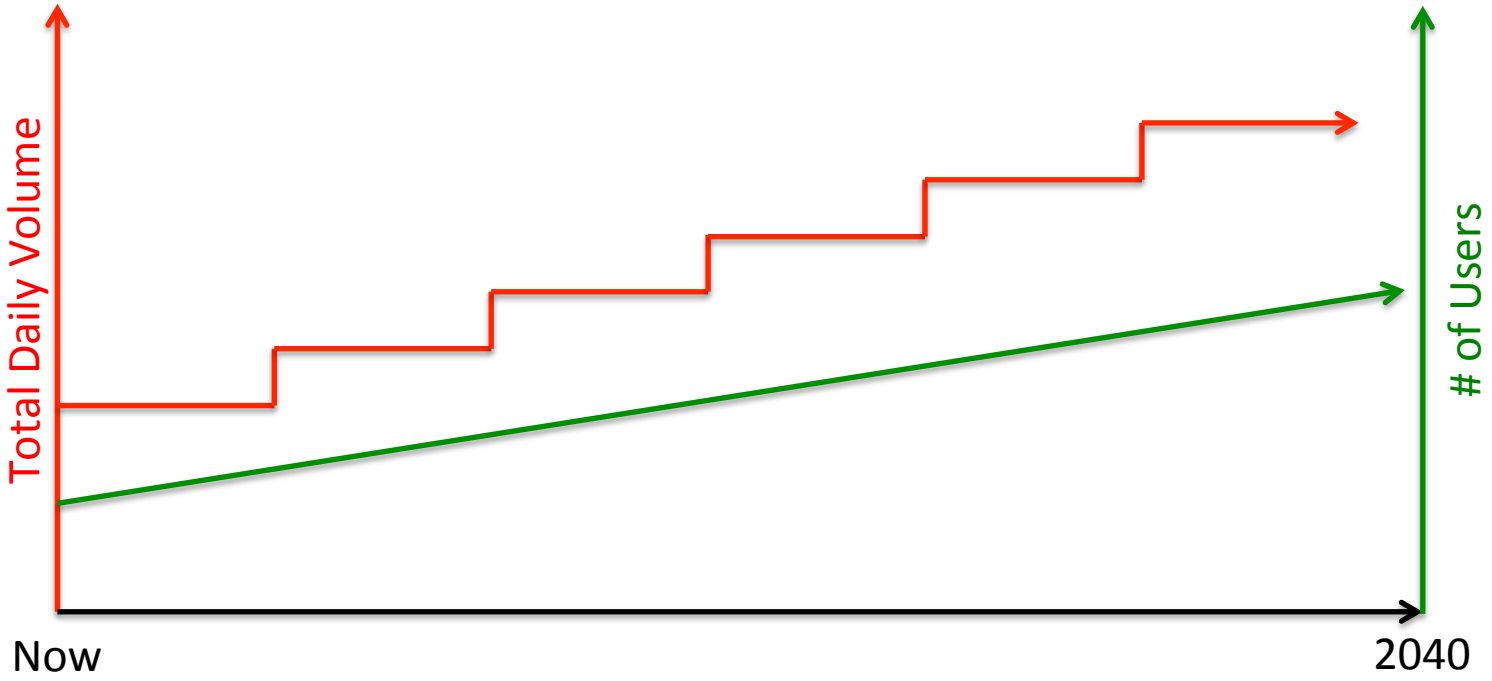
	Service Hours	Asset Hours	# of Events	Return Data Volume	Forward Data Volume	Pass Duration
Service Hours	1.000	0.824	0.791	0.753	0.698	-0.023
Asset Hours	0.824	1.000	0.849	0.416	0.349	-0.054
# of Events	0.791	0.849	1.000	0.503	0.323	-0.280
Return Data Volume	0.753	0.416	0.503	1.000	0.895	-0.084
Forward Data Volume	0.698	0.349	0.323	0.895	1.000	-0.017
Pass Duration	-0.023	-0.054	-0.280	-0.084	-0.017	1.000

Modeling the (R)evolution



- User model will follow a power law, **defined by highest TDV customer** and **# of users**
- Pass duration is uncorrelated with TDV
- Monthly unique users 40% greater than unique daily users
- Annual unique users 50% greater than unique monthly users

Future Work



- Define TDV anchor user projection
- Define # of users projection
- Further analyze datasets to discover more empirical laws
- Update analysis based on fresh (2016) data for SCMM and SN schedule database
- Cubesats!